The Universe as a Tapestry of Quantum Cells: A New Cyclic and Eternal Vision

A cosmological model integrating symmetries, quantum entanglement, and discrete spacetime proposes an eternal, dynamic, and continuously self-feedbacking cosmos, offering answers to the current tensions in cosmology.

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Introduction: Beyond the Big Bang

The Big Bang model has been extraordinarily successful: it explains the expansion of the universe, the cosmic microwave background (CMB), and the abundance of light elements. However, it carries uncomfortable questions. What happened at the initial singularity? Why is the universe so homogeneous on large scales? Why is the expansion accelerating? And, more recently, why do measurements of the Hubble constant (the current expansion rate) from the CMB and from local sources disagree?

In the last decade, alternatives have emerged aiming to go beyond the Big Bang. Some propose an eternal universe with infinite cycles of expansion and contraction. Others invoke quantum gravity or the discrete structure of spacetime. Now, a new theoretical framework integrates all these ideas under one umbrella: eternal cyclic universes, regulated by quantum entanglement, and organized as a tapestry of cosmic “cells” connected by spacetime itself.

This article reviews the pillars of this proposal, shows how it resolves fundamental problems, and explains how it could be tested with current and future observations.

1. The Power of Symmetries: From Noether to the Eternal Universe

One of the deepest principles of physics is that every symmetry corresponds to a conservation law. Emmy Noether's theorem (1915) states that if the laws of nature do not change under time translations, energy is conserved; under space translations, momentum is conserved; under rotations, angular momentum is conserved.

In cosmology, these symmetries appear broken. For example, the universe expands, so energy is not globally conserved in general relativity. Moreover, time moves in one direction (the thermodynamic arrow) due to increasing entropy. For an eternal universe, this is a challenge: how can it be eternal if entropy keeps increasing?

The answer lies in conceiving deeper symmetries, such as CPT symmetry (charge, parity, time reversal). A globally CPT-symmetric universe can consist of two halves: our universe with the forward time arrow and a "mirror universe" with the backward arrow, meeting at a point of minimum entropy. That point would be the Big Bang, but not an absolute beginning—rather a transition point in an eternal cosmos.

Such ideas lay the groundwork for a cyclic and eternal cosmology, where each cycle has its own Big Bang and entropy increase, but the total system remains in equilibrium.

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2. Quantum Entanglement: The Hidden Engine of the Cosmos

One of the most revolutionary discoveries of quantum physics is entanglement: two particles can be non-locally correlated, so that measuring one instantly affects the state of the other, regardless of distance. Einstein called this “spooky action at a distance,” and it has been verified in laboratories over hundreds of kilometres, and even recently in high-energy collisions at the LHC with top-quark pairs.

Could entanglement be relevant on cosmological scales? The proposal we explore says yes. A network of entangled particles throughout the universe can act as a regulator of expansion. This network adds an extra term to the Friedmann equations (which govern cosmic expansion), which we call Q.

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}(\rho_{\text{matter}}a^{-3} + \rho_{\text{radiation}}a^{-4}) - \frac{k}{a^2} + \frac{\Lambda}{3} + Q$$

The Q term depends on the number of entangled pairs, their coherence, and a collective phase. Essentially, when the universe is small and dense, entanglement is strong and Q can be large; as it expands, Q dilutes. This effect can accelerate or decelerate the expansion depending on the phase, and can even produce late-time acceleration similar to dark energy without the need for an ad hoc cosmological constant.

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3. Causal Sets: Discrete Spacetime with an Infinite Past

For the universe to be eternal and avoid the Big Bang singularity, we need a theory of spacetime that does not collapse to infinite densities. Causal set theory proposes that spacetime is made of discrete “atoms” (events) related by a causal order. There is no continuity: geometry emerges from the combinatorics of these points. Crucially, these sets can have an infinite past: there is no first event. Thus, the Big Bang is not a singularity but a high-density point within a causal sequence extending eternally into the past.

In this framework, quantum entanglement appears naturally as correlations between events sharing a common causal past. Combining causal sets with the Q term yields a scenario where each cosmic cycle (expansion, contraction, bounce) is linked to the next through the memory preserved by the entanglement network. That memory is key: it allows conditions of the previous cycle to influence the new one, explaining why the primordial fluctuations have the spectrum we observe.

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4. The Complete Cycle: An Eternal Dance between Contraction and Expansion

Let us now describe a complete cycle in this model. Each "cell" (our observable universe, but also other universes in a possible multiverse) goes through six phases:

1. **Contraction from maximum expansion**: density increases, the entanglement network intensifies, and coherence grows.
2. **Bounce**: at a minimum size (of the order of the Planck scale), the universe bounces. The quantum memory transfers to the new cycle information about the collective phase and coherence of the previous cycle.
3. **Early expansion**: the universe cools, nucleosynthesis occurs, and the CMB is emitted. The Q term modulates the expansion rate, affecting the sound horizon in the CMB.
4. **Intermediate expansion**: galaxies form. Dark matter (included as an additional component) grows under gravity, but its evolution may be altered by interaction with the quantum network.
5. **Late expansion**: the collective phase can generate an effective acceleration, explaining the observed dark energy.
6. **Maximum expansion and return**: expansion stops and contraction begins anew, closing the cycle.

The entanglement network acts as a clock and regulator: the phase Φ(t) determines the strength and sign of the Q term, while coherence D(t) controls how long this effect lasts. The evolution of Φ is similar to that of a system of coupled oscillators (Kuramoto model), allowing collective synchronisation phenomena.

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5. The Tapestry of Cells: A Multiverse of Entangled Universes

A natural extension is to imagine that our universe is not alone. If the fundamental spacetime (the causal set) is one single entity, it can be divided into regions or "cells", each with its own cycle dynamics. These cells are connected by causal relations and by entanglement between their particles.

In this tapestry of cyclic universes, the equations of each cell couple to those of its neighbours. For example, the phase Φ_i of a cell evolves under the influence of its neighbours' phases, with a term sin(Φ_j − Φ_i). This can lead to global synchronisation: all cells start their cycles simultaneously, explaining the observed homogeneity.

Depending on the network topology (1D, 2D, random, etc.), collective behaviours such as synchronised domains, phase waves, or even chaotic states can emerge. The numerical simulations we have developed allow exploration of these regimes and extraction of observable predictions.

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6. Resolving the Hubble Tension: A Younger Universe?

One of the most pressing problems in cosmology is the Hubble tension: local measurements of the Hubble constant (H0) give values of ~73–74 km/s/Mpc, while inferences from the CMB under the standard ΛCDM model give ~67–68

km/s/Mpc. This discrepancy, at 5σ significance, suggests that something is missing in our understanding of early expansion.

In our model, the Q term can act as early dark energy that accelerates expansion before recombination, reducing the sound horizon in the CMB. This allows the same CMB data to yield a higher H0, in line with local measurements. Numerical simulation of the cycle shows that, by choosing the entanglement parameters appropriately, the required adjustment can be achieved.

Moreover, coupling between cells (if our universe is part of a tapestry) can modify the expansion history in an even richer way, offering a natural mechanism to explain the tension without resorting to exotic components.

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7. Dark Matter and the S8 Tension: Slower Growth

Another less well-known but equally significant discrepancy is the S8 tension, which measures the amplitude of matter fluctuations. Gravitational lensing data (e.g., from KiDS and DES telescopes) point to a lower value than inferred from the CMB. This suggests that matter has clustered more slowly than predicted by ΛCDM.

In our model, dark matter can interact with the entanglement network. A simple coupling is to allow some entanglement energy to convert into dark matter at each bounce, or to make the evolution of dark matter density depend on the phase Φ. These interactions can suppress structure growth on small scales, reducing σ8 and alleviating the S8 tension.

Thus, the same mechanism that regulates expansion (entanglement) also affects galaxy formation, providing a unified solution to two major cosmological tensions.

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8. Observational Signatures: How to Test the Model

A cosmological model is useful only if it can be falsified by observations. Our proposal leaves several distinctive imprints:

- **Primordial non-Gaussianity**: while simple inflation predicts very small non-Gaussianity ($f_{NL} << 1$), the bounce process with quantum memory can generate f_{NL} of order unity or larger, especially of local or equilateral type. Future CMB experiments (CMB-S4, Simons Observatory) will detect or constrain these values.
- **Large-scale correlations**: entanglement between distant regions can produce an excess correlation in the galaxy two-point function on scales larger than the particle horizon, which does not occur in ΛCDM. Surveys such as Euclid and the Rubin Observatory will measure these correlations with high precision.
- **Parity asymmetries**: recent observations show that spiral galaxies have a preferred handedness (e.g., more counter-clockwise than clockwise). In our model, the collective phase Φ can have a net helicity inherited from previous cycles, producing a preferred direction on the sky that might manifest in the CMB (the so-called "axis of evil") and in galaxy alignments.
- **CMB power spectrum**: the Q term modifies the shape of the acoustic peaks. A detailed analysis of Planck data and future experiments can determine whether there is evidence of early dark energy with the functional form we propose.

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9. Conclusion: Towards a New Cosmology

The model we have outlined—an eternal cyclic universe, regulated by quantum entanglement, with discrete spacetime organised into a tapestry of interacting cells—represents a paradigm shift from the standard Big Bang. It replaces the initial singularity with a smooth bounce, explains homogeneity and isotropy as

the result of collective synchronisation, and naturally generates accelerated expansion and dark matter as emergent effects.

Moreover, it offers observational predictions that will allow it to be tested in the coming years. If the Hubble and S8 tensions persist and new measurements of non-Gaussianity and large-scale correlations confirm the current anomalies, models of this kind could become the new foundation of cosmology.

But beyond its explanatory power, this framework invites us to conceive the cosmos as a quantum organism: a network of cells that breathe, synchronise, and transmit information through entanglement. A universe that was not born but has always been there, in an eternal cycle of creation and recreation.

References for Further Reading

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